RECOMMENDATION ITU-R M.1464*

CHARACTERISTICS OF AND PROTECTION CRITERIA FOR RADIONAVIGATION AND METEOROLOGICAL RADARS OPERATING IN THE FREQUENCY BAND 2 700-2 900 MHz

(Question ITU-R 35/8)

(2000)

The ITU Radiocommunication Assembly,

considering

a) that antenna, signal propagation, target detection, and large necessary bandwidth characteristics of radar to achieve their functions are optimum in certain frequency bands;

b) that the technical characteristics of radionavigation and meteorological radars are determined by the mission of the system and vary widely even within a band;

c) that the radionavigation service is a safety service as specified by RR No. S4.10 and harmful interference to it cannot be accepted;

d) that considerable radiolocation and radionavigation spectrum allocations (amounting to about 1 GHz) have been removed or downgraded since WARC-79;

e) that some ITU-R technical groups are considering the potential for the introduction of new types of systems (e.g. fixed wireless access and high density fixed and mobile systems) or services in bands between 420 MHz and 34 GHz used by radionavigation and meteorological radars;

f) that representative technical and operational characteristics of radionavigation and meteorological radars are required to determine the feasibility of introducing new types of systems into frequency bands in which the latter are operated;

g) that procedures and methodologies are needed to analyse compatibility between radionavigation and meteorological radars and systems in other services.

h) that ground-based radars used for meteorological purposes are authorized to operate in this band on a basis of equality with stations in the aeronautical radionavigation service (see RR No. S5.423);

j) that aeronautical radionavigation and meteorological radars operate in the 2 700-2 900 MHz band,

recommends

1 that the technical and operational characteristics of the aeronautical radionavigation and meteorological radars described in Annex 1 be considered representative of those operating in the frequency band 2 700-2 900 MHz;

2 that Recommendation ITU-R M.1461 be used as a guideline in analysing compatibility between radionavigation and meteorological radars with systems in other services;

* This Recommendation should be brought to the attention of the International Civil Aviation Organization (ICAO) and the World Meteorological Organization (WMO).

3 that the criterion of interfering signal power to radar receiver noise power level (*I*/*N*) of –6 dB be used as the required protection level for the radionavigation and meteorological radars, and that this represents the net protection level if multiple interferers are present.

NOTE 1 – This Recommendation will be revised as more detailed information becomes available. It should be noted that work is already in progress within ITU-R addressing specifically the compatibility between radars in the band 2 700-2 900 MHz and IMT-2000 systems.

ANNEX 1

Characteristics of aeronautical radionavigation and meteorological radars

1 Introduction

The band 2 700-2 900 MHz is allocated to the aeronautical radionavigation service on a primary basis and the radiolocation service on a secondary basis. Ground-based radars used for meteorological purposes are authorized to operate in this band on a basis of equality with stations in the aeronautical radionavigation service (see RR No. S5.423).

The aeronautical radionavigation radars are used for air traffic control (ATC) at airports, and perform a safety service (see RR No. S4.10). Indications are that this is the dominant band for terminal approach/airport surveillance radars for civil air traffic worldwide. The meteorological radars are used for detection of severe weather elements such as tornadoes, hurricanes and violent thunderstorms. These weather radars also provide quantitative area precipitation measurements so important in hydrologic forecasting of potential flooding. This information is used to provide warnings to the public and it therefore provides a safety-of-life service.

2 Technical characteristics

The band 2 700-2 900 MHz is used by several different types of radars on land-based fixed and transportable platforms. Functions performed by radar systems in the band include ATC and weather observation. Radar operating frequencies can be assumed to be uniformly spread throughout the band 2 700-2 900 MHz. Table 1 contains technical characteristics of representative aeronautical radionavigation and meteorological radars deployed in the 2 700-2 900 MHz band. This information is sufficient for general calculation to assess the compatibility between these radars and other systems.

2.1 Transmitters

The radars operating in the band 2 700-2 900 MHz use continuous wave (CW) pulses and frequency modulated (chirped) pulses. Cross-field, linear beam and solid state output devices are used in the final stages of the transmitters. The trend in new radar systems is toward linear beam and solid state output devices due to the requirement of Doppler signal processing. Also, the radars deploying solid state output devices have lower transmitter peak output power and higher pulsed duty cycles approaching 10%. There is also a trend towards radionavigation radar systems that use frequency diversity.

Typical transmitter RF emission bandwidths of radars operating in the band 2 700-2 900 MHz range from 66 kHz to 6 MHz. Transmitter peak output powers range from 25 kW (74 dBm) for solid state transmitters to 1.4 MW (91.5 dBm) for high power radars using klystrons.

TABLE 1

Characteristics of aeronautical radionavigation/meteorological radars in the band 2 700-2 900 MHz

Characteristics	Radar A	Radar B	Radar C	Radar D	Radar E
Platform type (airborne, shipborne, ground)	Ground, ATC				Ground, weather
Tuning range (MHz)	2 700-2 900				2 700-3 000
Modulation	P0N		P0N, Q3N	P0N	
Tx power into antenna	1.4 MW	1.32 MW	25 kW	450 kW	500 kW
Pulse width (μs)	0.6	1.03	1.0, 89	1.0	1.6 (short pulse) 4.7 (long pulse)
Pulse rise/fall time (μs)	0.15-0.2		0.5/0.32 (short pulse) 0.7/1 (long pulse)		0.12
Pulse repetition rate (pps)	973-1 040 (selectable)	1 059-1 172	722-935 (short pulse) 788-1 050 (long pulse)	1 050	318-1 304 (short pulse) 318-452 (long pulse)
Duty cycle (%)	0.07 maximum	0.14 maximum	9.34 maximum	0.1 maximum	0.21 maximum
Chirp bandwidth (MHz)	Not applicable		2	Not applicable	
Phase-coded sub-pulse width	Not applicable				
Compression ratio	Not applicable		89	Not applicable	
RF emission bandwidth: –20 dB 3 dB	 6 MHz	 5 MHz 600 kHz	 2.6 MHz (short pulse) 5.6 MHz (long pulse) 1.9		 4.6 MHz 600 kHz
Output device	Klystron		Solid state transistors, Class C	Magnetron	Klystron
Antenna pattern type (pencil, fan, cosecant-squared, etc.)	Cosecant-squared +30°		Cosecant-squared 6° to +30°		Pencil
Antenna type (reflector, phased array, slotted array, etc.)	Parabolic reflector				
Antenna polarization	Vertical or LHCP	Vertical or RHCP	Circular or linear	Vertical or LHCP	Linear: vertical and horizontal
Antenna mainbeam gain (dBi)	33.5		34	32.8	45.7

TABLE 1 *(end)*

Characteristics	Radar A	Radar B	Radar C	Radar D	Radar E
Antenna elevation beamwidth (degrees)	4.8			4	0.92
Antenna azimuthal beamwidth (degrees)	1.35	1.3	1.45	1.6	0.92
Antenna horizontal scan rate (degrees/s)	75			90	18
Antenna horizontal scan type (continuous, random, 360°, sector, etc.)	360°				
Antenna vertical scan rate (degrees/s)	Not applicable				14 steps in 5 min
Antenna vertical scan type (continuous, random, 360°, sector, etc.) (degrees)	Not applicable		+2.5 to –2.5	Not applicable	Fixed steps: 0.5-20
Antenna sidelobe (SL) levels (1st SLs and remote SLs)		+7.3 dBi	+9.5 dBi 3.5°		+20 dBi
Antenna height (m)	8				30
Receiver IF 3 dB bandwidth	5.0 MHz	653 kHz	15 MHz		630 kHz
Receiver noise figure (dB)	4.0 maximum		3.3	2.7	2.1
Minimum discernible signal (dBm)	–110	–108	–110	–112	–115
Receiver front-end 1 dB gain compression point (dBm)		–20			–17
Receiver on-tune saturation level (dBm)		–45			–10
Receiver RF 3 dB bandwidth	2-2.3 MHz	10 MHz	280.6 MHz		1.6 MHz
Receiver RF and IF saturation levels and recovery times					–10 dBm, 1 μs
Doppler filtering bandwidth (Hz)		95 per bin			Estimate 95
Interference-rejection features	Feedback enhancer	(1)			(2)
Geographical distribution	Worldwide				
Fraction of time in use (%)	100				

(1) Sensitivity time control (STC), constant false alarm rate (CFAR), selectable pulse repetition frequencies (PRFs), asynchronous pulse rejection, Doppler filtering, saturating pulse removal.

(2) Doppler filtering and saturating pulse removal.

2.2 Receivers

The newer generation radar systems use digital signal processing after detection for range, azimuth and Doppler processing. Generally, included in the signal processing are techniques used to enhance the detection of desired targets and to produce target symbols on the display. The signal processing techniques used for the enhancement and identification of desired targets also provides some suppression of low-duty cycle interference, less than 5%, that is asynchronous with the desired signal.

Also, the signal processing in the newer generation of radars use chirped pulses which produce a processing gain for the desired signal and may also provide suppression of undesired signals.

Some of the newer low power solid state transmitters use high-duty cycle, multiple receiver channel signal processing to enhance the desired signal returns. Some radar receivers have the capability to identify RF channels that have low undesired signals and command the transmitter to transmit on those RF channels.

2.3 Antennas

Only parabolic reflector-type antennas are used on radars operating in the 2 700-2 900 MHz band. The ATC radars have a cosecant-squared elevation pattern, while the meteorological radars have a pencil beam antenna pattern. Since the radars in the 2 700-2 900 MHz band perform ATC and weather observation functions the antennas scan 360° in the horizontal plane. Horizontal, vertical and circular polarizations are used. Newer generation radars using reflector-type antennas have multiple horns. Dual horns are used for transmit and receive to improve detection in surface clutter. Also, multiple horns, stack beam, reflector antennas are used for three-dimensional radars. The multiple horn antennas will reduce the level of interference. Typical antenna heights for the aeronautical radionavigation and meteorological radars are 8 m and 30 m above ground level, respectively.

3 Protection criteria

The desensitizing effect on radionavigation and meteorological radars from other services of a CW or noise-like type modulation is predictably related to its intensity. In any azimuth sectors in which such interference arrives, its power spectral density can simply be added to the power spectral density of the radar receiver thermal noise, to within a reasonable approximation. If power spectral density of radar-receiver noise in the absence of interference is denoted by N_0 and that of noise-like interference by I_0, the resultant effective noise power spectral density becomes simply $I_0 + N_0$. An increase of about 1 dB would constitute significant degradation, equivalent to a detection-range reduction of about 6%. Such an increase corresponds to an $(I + N)/N$ ratio of 1.26, or an I/N ratio of about –6 dB. This represents the aggregate effect of multiple interferers, when present; the tolerable I/N ratio for an individual interferer depends on the number of interferers and their geometry, and needs to be assessed in the course of analysis of a given scenario. If CW interference were received from most azimuth directions, a lower I/N ratio would need to be maintained.

The aggregation factor can be very substantial in the case of certain communication systems, in which a great number of stations can be deployed.

The effect of pulsed interference is more difficult to quantify and is strongly dependent on receivers/processor design and mode of operation. In particular, the differential processing gains for valid-target return, which is synchronously pulsed, and interference pulses, which are usually asynchronous, often have important effects on the impact of given levels of pulsed interference. Several different forms of performance degradation can be inflicted by such desensitization. Assessing it will be an objective for analyses of interactions between specific radar types. In general, numerous features of radiodetermination radars can be expected to help suppress low-duty cycle pulsed interference, especially from a few isolated sources. Techniques for suppression of low-duty cycle pulsed interference are contained in Recommendation ITU-R M.1372 – Efficient use of the radio spectrum by radar stations in the radiodetermination service.

4 Operational characteristics

4.1 Meteorological radars

The technical characteristics of a representative weather radar, that predominately operates in the 2 700-2 900 MHz band, are depicted in Table 1 as radar E. However, this radar can operate up to 3 000 MHz. This is the primary weather radar system used for flight planning activities and is often collocated at airports worldwide, to provide accurate weather conditions for aircraft. Therefore, these radars are also in operation 24 h per day.

This radar utilizes Doppler radar technology to observe the presence and calculate the speed and direction of motion of severe weather elements such as tornadoes, hurricanes and violent thunderstorms. Radar E also provides quantitative area precipitation measurements so important in hydrologic forecasting of potential flooding. The severe weather and motion detection capabilities offered by this radar contributes toward an increase in the accuracy and timeliness of warning services. Radar E excels in detecting the severe weather events that threaten life and property, from early detection of damaging winds to estimating rainfall amounts for use in river and flood forecasting.

These radars are an integrated network spanning the entire United States of America, Guam, Puerto Rico, Japan, South Korea, China and Portugal. The 2 700-2 900 MHz band offers excellent meteorological and propagation characteristics for weather forecast and warning capabilities. Planned enhancements to the radar should extend its service life to the year 2040.

4.2 Aeronautical radionavigation radars

Airport surveillance radars operate throughout the world in the band 2 700-2 900 MHz. Four representative types of ATC radars are depicted in Table 1, as radars A through radar D. These radars perform airport surveillance for terminal approach control and normally require surveillance of a full 360° sector use on a round-the-clock schedule. Radars A through C are typically located at airports and every major airport is usually equipped with a similar radar system. Radars A and B are the current generation of radars deployed. Radar C is representative of the next generation system, which should augment and/or replace radars A and B after the year 2010. Radar D is a transportable system used for ATC at airfields where there are no existing facilities. When in use, radar D is operated 24 h per day. Some of these radars operate in a frequency diversity mode, which requires two frequency assignments per radar.